In situ conservation of butterflies through establishment of butterfly gardens: A case study at Peechi, Kerala, India

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***In situ* propagation of butterflies was attempted through establishment of a butterfly garden in a 0.5 ha degraded moist deciduous forest patch at the Kerala Forest Research Institute campus at Peechi, Kerala, India. Creation of butterfly habitats through landscaping and introduction of suitable host plants to sustain different species of butterflies were the major activities undertaken. There was tremendous increase in the butterfly population with 4509 sightings of butterflies belonging to 43 species after 15 months and 10,502 sightings of butterflies belonging to 56 species after 30 months. These included eight species that are endemic to the Western Ghats and ten species having protected status under the Indian Wildlife Act. Investigations on the relationship between the occurrence of different butterflies and the weather conditions revealed that an average temperature ranging between 25 and 26°C was most favourable for many butterflies followed by 23 and 25°C as well as 27 and 29°C. Similarly, atmospheric humidity ranging between 80 and 100% was the most preferred range followed by 60 and 80%. With regard to daily rainfall, 50 mm was the most favourable followed by 50–100 mm rainfall. Heavy rainfall was found to be unfavourable since few butterflies were observed above 100 mm of daily rainfall. By regulating humidity and temperature, it was possible to manipulate local populations of butterflies, particularly danaid butterflies. More or less continuous population was noticed for some Danaidae, Lycaenidae, Papilionidae and Pieridae, which also developed resident populations in the study area. Strategies were also standardized for setting up butterfly gardens.**

Keywords: Butterfly garden, conservation, humidity, rainfall, temperature.

THE role of butterfly gardens for *in situ* conservation and for promoting environmental education is well recognized[1–3]. Pyle[4] has given an account of butterfly exhibitory and butterfly farming ventures in various countries. As a business-cum-educational enterprise, butterfly gardens and butterfly houses are becoming increasingly popular in many countries such as Australia, Singapore, Malaysia, Papua New Guinea, the UK and Canada. According to an estimate made in 1987, Britain has 50–60 butterfly houses attracting five million visitors annually and the gate collections exceeded 5 million pounds[5]. In North America, more than a dozen major exhibits are already operating and many units are under construction. Similarly, the Butterfly Garden of the Niagara Parks Commission at Ontario, which is a $15 million dollar facility, attracts about 20,000 visitors during weekends[6]. India, with its rich butterfly fauna holds great potential for alternative income production by incorporating butterfly exhibitory in ecotourism enterprises. Development of such enterprises is reported to be a suitable option for rural upliftment programmes. Villages near biodiversity hotspots like the northeastern Himalayas and the Western Ghats were suggested as ideal areas for establishment of such enterprises[7]. Recently, in November 2006, a Butterfly Park was established at the Bannerghatta Biological Park, Bangalore. The park, established over an area of 3.04 ha, has a butterfly garden, butterfly conservatory, museum and a curio shop.

Due to unscientific management of natural resources, much of our native flora and fauna are fast disappearing and there is an urgent need to restore our lost habitats to conserve biodiversity. Establishment of butterfly gardens helps maximize butterfly diversity and abundance in urban and suburban areas, conserving species that might otherwise become rare or even disappear. By involving the public in cultivating a butterfly garden, they will appreciate the needs of individual species, and this will also kindle conservation awareness among them. It was in this context that the present investigation on the *in situ* conservation of butterflies through butterfly gardens was undertaken. A prototype of the garden was set up in a 0.5 ha patch of degraded forest in the Kerala Forest Research Institute (KFRI) campus at Peechi, mainly to standardize the methodologies for establishing such gardens in Kerala[8].

Materials and methods

Site selection

The site selected for establishing the garden was a highly degraded, moist, deciduous forest patch within the KFRI

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campus, which has been under protection since 1975. The terrain is undulating and hilly in nature with steep slopes and a more or less plain ridge. The slowly regenerating vegetation of this area included a few trees of *Bombax malabaricum*, *Ailanthus triphysa*, *Tectona grandis*, *Grewia tiliaefolia* and *Terminalia bellerica*, mainly along the slopes. Ground vegetation comprised mostly of shrubs like *Lantana camara* and *Chromolaena odoratum*.

Landscaping and introduction of host plants to recreate butterfly habitats

The basic design of the garden was prepared based on the terrain and geographical features of the area (Figure 1). Foraging and breeding are the important activities of butterflies. Hence, while designing the components of the garden, due consideration was given to the habitat preferences of various groups of butterflies. Different butterfly habitats were recreated through landscaping and by setting up lawns, rock gardens, streams, bushes, lianas, creepers and hedges at appropriate locations. In order to facilitate observation of butterflies present in the various recreated habitats, a nature trail was also laid out traversing the different habitats (Figure 2).

Since environmental education of the public was the main target of this programme, care was taken to make an exhibitory of the butterflies in a special area of the garden. The plain area along the ridge was developed for this purpose (butterfly exhibit area). Landscaping of this area included setting up of a circular canal 0.5 m wide and 60 cm deep (Figure 3 *a* and *b*). The island thus formed was planted with butterfly aggregation plants such as *Heliotropium keralense* and *Crotalaria retusa* in order to facilitate roosting of danaid butterflies. Along one portion of the exhibit area, a rock garden was developed where plants such as *Cycas*, palms, *Cuphea*, *Cassia tora*, *Jatropha podogirica*, *Kalanchoe suarezensis* and *K. pinnata* were introduced. The remaining area was planted with *Wattakaka volubilis*, *Thottea siliquosa*, *Tylophora indica*, *T. camosa*, *Asclepias* sp., *Calotropis giganteum*, *Carissa carandus*, *Ruta graveolens*, *Aegle marmelos*, *Albizia lebbeck*, *Cassia* spp., *Citrus* spp., *Murraya koenigii*, *Mussaenda luteola*, *M. laxa* and *Ixora*. All these species are known to support a variety of lycaenid, pierid, satyrid and nymphalid butterflies.

The slopes which had tall trees were found to be a good habitat for many swift-flying butterflies, especially the papilionids. This area was developed into a butterfly forage area (Figure 4 *a* and *b*), mainly by favouring colonization of wild vegetation and through introduction of host plants suitable for large butterflies.

For this, nectar plants like *Clerodendrum capitatum*, *Cassia* spp., *L. camara*, and larval food plants such as *Michelia champaca* (food plant of *Graphium doson* and *G. agamemnon*), *Zinnamom zeylanicum* (food plant of *Chilasa clytia*), *Zanthoxylum rhetsa* (food plant of *Papilio helenus* and *P. crino*), *A. marmelos* (food plant of *Papilio demoleus* and *P. polytes*) and *Citrus aurantia* (food plant of *P. polytes* and *P. polymnestor*) were introduced. Care was also taken to retain the ground vegetation and to leave the accumulated dry leaves and other debris undisturbed in order to offer suitable habitats for satyrid butterflies. Thickets of palms, *Heliconia* and ornamental varieties of *Musa* were introduced to develop dense vegetation conducive to the breeding of satyrid butterflies[8].

Selection of host plants for introduction in the garden was on the basis of the butterfly fauna present in this region. In order to decide upon the host plants to be introduced, a preliminary survey lasting for about a month was carried out to gather general information on the local

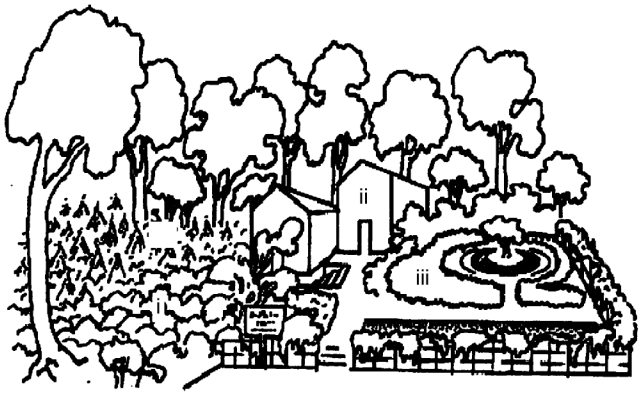

Figure 1. Layout of the butterfly garden. (i) Butterfly forage area; (ii) Insectary, and (iii) Butterfly exhibit area.

Figure 2. Main entrance to the garden with the trekking path leading to different habitats.

Figure 3. View of butterfly exhibit area with circular canal prior to introduction of host plants (*a*) and after landscaping and introduction of host plants (*b*).

Figure 4. View of butterfly forage area before (*a*) and after (*b*) establishment of host plants. The nectar plant *Clerodendrum paniculatum* in full bloom can be seen.

fauna. Based on data already available on the host plant preferences of various butterflies, a list of larval and adult host plants of local butterflies was prepared and attempts were made to raise them in a nursery. As far as possible, the existing vegetation was retained and native plants were preferred for introduction. Initially, the wild plants were field-collected while the domesticated ones were procured from commercial gardens. The plants were introduced in a phased manner. Data pertaining to the butterfly host plants already present in the study area and those subsequently introduced are given in Appendix 1.

The garden was fenced using pre-fabricated steel frames over which creepers such as *Passiflora edulis*, *Aristolochia indica*, *Ipomoea* sp. and *Wattakaka volubilis* were grown (Figure 2). Along the inner side of the fence, on the sides of the nature trail as well as in open areas present in the garden, nectar plants such as *Ixora* spp., *Cassia* spp., *Allamanda cathartica*, *Hibiscus rosa-sinensis*, *Cuphea miniata*, *Zinnia haageana*, marigold, *Clerodendrum capitatum* and *L. camara* were introduced. Because of the mixed assemblage of a variety of larval and adult host plants, a number of butterflies belonging to diverse groups became general visitors to this area.

Monitoring and recording of butterfly population trends

In order to evaluate the effect of habitat enrichment, regular monitoring of the fauna was carried out by making daily transect counts and recording their number for the entire study period from June 1998 to November 2000. For this, a 175 m long and 1.5 m wide line transect traversing the garden area newly planted with nectar sources and in the area containing wild sources of nectar and native tree species was laid out. Along this transect, two fixed locations were selected for sampling – one in the garden area and the other in the area containing wild nectar sources.

A 10 min visual survey was done during each sampling period. The butterflies were identified on wing and the date of observation, number of species and individuals were recorded. Two transect counts, viz. a forenoon count between 10.30 and 11.30 h, and an afternoon count bet-

ween 02.30 h and 03.30 h were made at the two locations[9]. Counts were not taken during heavy rains and when it was windy.

Daily recordings of temperature, humidity and rainfall obtained from the automatic weather station at KFRI were used in the analysis. Butterflies were identified by referring to the KFRI insect collection and the literature[10,11]. Classification and nomenclature followed were after D'Abrera[10].

Analysis of data

Seasonal index: For comparing butterfly population trends, the seasonal index for each month was calculated using the following formula:

$$\text{Season index} = \frac{\text{Month-wise mean}}{\text{Overall mean}} \times 100,$$

where month-wise mean is the mean number of butterflies for a given family sighted during the study period and overall mean is the mean of all month-wise means. By calculating the seasonal index it was possible to interpret the mean/percentage of occurrence of butterflies in a given month in relation to the overall mean monthly sightings.

Correlation with weather conditions: In order to study the relationship between butterfly occurrence and weather conditions, the correlation coefficient between the number of sightings per month and the various weather parameters was computed. For this, the total number of butterflies sighted per month belonging to each family and weather parameters such as monthly mean temperature, humidity and total rainfall for the study period were recorded.

Results

Butterfly fauna

Prior to landscaping and introduction of host plants, although 46 species were recorded in the vicinity of the study area, most of these were represented by a few individuals and spotted at long intervals. Following introduction of appropriate larval and adult host plants, there was a sharp increase in the number of butterflies visiting the area, both in terms of individuals and species. During the first half of this study (after 15 months), there were 4509 sightings of individuals belonging to 43 species and in the second half (after 30 months), 5993 sightings of individuals belonging to 50 species were recorded (Appendix 2). After 30 months of monitoring, a total of 10,502 sightings of individuals belonging to 56 species were recorded. Continuous monitoring and field observations showed a steady increase in sightings with 69 species of butterflies being recorded in the study area. Among the various butterflies recorded, about a dozen were quite common in the area and the remaining were found only during certain months of the year. The butterflies recorded in this study included eight species that are Western Ghats endemics and ten species having protected status under the Wildlife (Protection) Act[12].

Habitat association of butterflies in the garden

The exhibit area showed abundance of several butterflies that are fond of bright sunshine such as *Troides minos*, *Papilio demoleus*, *P. polytes*, *Pachliopta hector*, *P. pandiyana* (Papilionidae); *Catopsilia* sp., *Eurema* sp. (Pieridae); *Jamides* sp., *Talicada nyseus*, *Castalius rosimon*, *Everes* sp. (Lycaenidae); *Euploea core*, *Tirumala limniace*, *T. septentrionis*, *Danaus genutia*, *Parantica aglea* (Danaidae); *Junonia hierta*, *J. atlites*, *J. iphita*, *J. precis* and *Hypolimnas misippus* (Nymphalidae). These species were found to feed on the flowers of *L. camara*, *Cuphea* sp. and *Ixora* sp. Among these, the danaids formed large aggregations with populations ranging from 150 to 600 on *C. retusa* (Figure 5) and *H. keralense*. These butterflies were observed to lacerate the foliage with the claws of the first pair of legs and then feed on the sap exuding from the foliage. A pyrrolizidine alkaloid contained in these plants is known to be essential for the development of the male pheromone glands of these butterflies[13]. The number of individuals involved in aggregation was increasing year after year, which is attributed to restoration of appropriate butterfly habitats in the area. However, during the dry months no aggregation was observed, probably due to migration to the cooler habitats in the catchment area of the Peechi dam situated about 5 km away from the study site. Here, the butterflies

Figure 5. Aggregation of blue tiger on *Crotalaria retusa* in the butterfly garden at KFRI.

were found perched on twigs of understorey about a metre above the ground, in clusters of two to six. Such aggregation of danaid butterflies has been noticed since 1996 every year at Silent Valley, Sholayar, Thenmala and Nilambur (George Mathew, unpublished data). However, further systematic observations are necessary to confirm whether this aggregation is following migration or not. Obviously, the site determinants for these dry-season aggregations appear to be the simultaneous presence of shade, water and nectar sources.

The forage area having tall native trees providing cool shade mixed with sunlit patches offered favourable habitats for several papilionids (*Papilio buddha*, *P. polymnestor*, *P. helenus*, *P. paris*, *Troides minos*, *Pachliopta pandiyana* and *Chilasa clytia*), which were observed to fly rapidly amid bushes and treetops, frequently feeding at the flower heads of *C. paniculatum* and *L. camara*. The cool, shaded areas amid dry leaves were occupied by the satyrids *Orsotrioena medus* and *Melanitis leda ismene*. Most sightings of satyrids were in the afternoon. The sombre-coloured hesperids as a group were inconspicuous, although some of them were observed nectaring in the late afternoon hours.

Seasonal population trends of butterflies in the garden

The seasonal index calculated from the total number of butterflies sighted during each month for 24 months from June 1998 to May 2000 is presented in Figure 6, under their respective groups.

Papilionidae: The population was present throughout the year, with maximum number of sightings observed in August 1998. The population showed a sharp decline during November 1998, probably due to heavy winds characteristic of these months (Figure 6). From December 1998 onwards, the population registered an increase and reached its peak in June 1999. The seasonal index reached a peak during June–August and showed a sharp decline in November. Thereafter, the population showed a steady increase. November to February were not suitable due to heavy winds and prevailing dry conditions.

Among the papilionids, the common rose (*Pachliopta aristolochiae*) was observed during all months of the year, with the lowest numbers in May and August. June had the highest count and a moderate population could be sustained in the remaining months. The common mormon (*P. polytes*) showed a peak in October and a sudden drop in November. This species was also observed throughout the year. In the case of the southern birdwing (*T. minos*), the population was observed from April to November, with highest numbers recorded in June and July. In the case of the common mime (*C. clytia*), population build-up was observed from February to August, with highest numbers recorded in April and lowest in July (Figure 7). The sudden decline in number was attributed to parasitism of larval and pupal stages.

Pieridae: The population was present throughout the year. Maximum number of sightings was recorded during November–December 1998. Population was low during June–August, probably due to rains. However, the number of sightings in September 1999 was considerably higher than in the previous year (Figure 6), which might be due to the establishment of host plants that have been introduced. In the case of the seasonal index, the highest value was in November and the lowest in July and August.

Catopsilia pomona, *C. pyranthe* and *Eurema blanda* were observed during all months of the year, except in May (*E. blanda*), and September and October (*Catopsilia* spp.). In the case of *E. blanda*, mass build-up was noticed during October–November (Figure 8).

Acraeidae: Since the sightings were obtained only in March to May in second year, no clear pattern in seasonal trends was available.

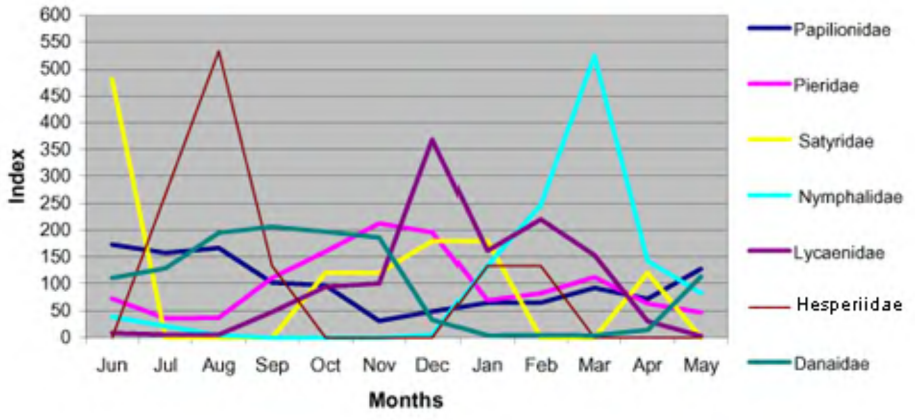

Figure 6. Seasonal index of different families of butterflies.

Satyridae: Members of this family are crepuscular and shade-loving in habitats and hence could not be effectively sampled. No consistent pattern was observed for the two years (Figure 6), although maximum count was recorded in June 1998. However, there were more sightings, particularly of the nigger (*O. medus*) and the evening brown (*M. leda ismene*) during 1998–99 compared to 1999–2000. The seasonal index showed nil values during July–September, February and March. The highest value was obtained in June. Since the number of sightings of members of this family was low, the data may not indicate the actual population trends.

Nymphalidae: Only a limited number of nymphalid species were observed. In 1999, a few sightings were recorded during January to March, which showed a decline till July. The highest count was obtained in March 2000. There were no sightings during September–November in both years (Figure 6). The drier half of the year from January to May appears to be favourable for this family. The seasonal index showed a steady increase from December reaching a peak in March, then a sudden decline in April and subsequent gradual decrease until August.

Lycaenidae: In the first year (1998–99), there was a peak in numbers during December 1998, which decreased in January 1999 and persisted until March 1999 (Figure 6). In the second year during December although the number of butterflies was not as high as in the previous year, a moderate population could be sustained for a longer period. This was due to the establishment of specific host plants like *Cycas circinalis*, *Kalanchoe suarezensis* and *K. pinnata*. During May to August, few individuals were recorded. The seasonal index showed a peak in December and decreased until August, after which it gradually increased.

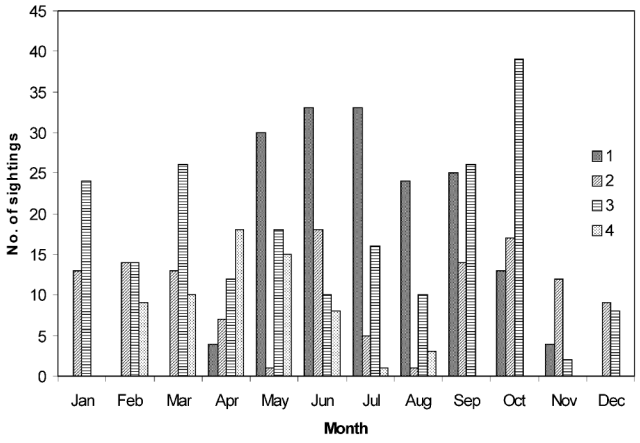

Figure 7. Seasonal trends of selected species of Papilionidae (January–December 1999). 1, *Troides minos*; 2, *Pachliopta aristolochiae*; 3, *Papilio polytes*; 4, *Chilasa clytia*.

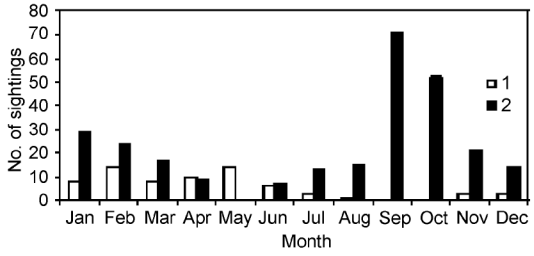

Figure 8. Seasonal trends of selected species of Pieridae (January–December 1999). 1, *Catopsilia* spp.; 2, *Eurema* spp.

Hesperiidae: Since the members of this family are not conspicuous, sampling was not adequate and the number of individuals sighted was low. Highest numbers were observed during August 1998 (Figure 6). The seasonal index showed the highest value during August and then a declining trend until October. The population registered an upward trend during January and February, and then declined from March to June.

Danaidae: The highest count was obtained in August 1998 followed by October 1999 (Figure 6). The counts in June 1999 were higher than those of June 1998, while the numbers observed in May 2000 exceeded those of May 1999. Similarly, the numbers observed in December 1998 had increased in the second year. In both the years, January–April had few individuals. However, in the second year, a moderate population could be sustained from December 1999 to April 2000. The increase in numbers observed in June and October 1999 was possibly due to establishment of larval host plants of the danaids, viz. *Holostemma annulare*, *Wattakakka volubilis*, *Calotropis gigantea*, *Ficus* spp., *Carissa carandus* and *Tylophora indica*. Irrigating the area by setting up sprinklers might have also contributed to a spurt in butterfly population in May 2000. The seasonal index remained more or less similar during June–November and thereafter declined sharply during December and remained at a low level until April. The population showed an increase during May.

Most of the danaids could be sustained in the field only from May to December. The blue tiger (*T. limniace*) was observed from May to December, with the highest numbers recorded in June. The dark blue tiger (*T. septentrionis*) was recorded from September to December. The striped tiger (*D. genutia*) was observed in June and July and September–November. The highest count was recorded in June. The common crow (*E. core*) is the only danaid that was observed in February and March. Highest count was recorded in June (Figure 9).

Overall population trend: Data generated by pooling the total number of sighting for all groups of butterflies during the period June 1998 to May 2000, showed that the families Papilionidae, Pieridae and Danaidae which were able to efficiently exploit the available resources, showed the highest numbers in the garden. It was also

observed that while several butterflies of Papilionidae and Pieridae showed a more or less continuous population trend for most part of the year with resident population in the study area, others of families Danaidae, Lycaenidae, Satyridae, Nymphalidae and Hesperiidae were mostly seasonal (Figure 10). *C. clytia* (Papilionidae); *Acraea violae* (Acraeidae); *Elymnias caudata* (Satyridae); *Talicada nyseus*, *Rathinda amor* (Lycaenidae); *P. aglea, T. septentrionis* (Danaidae) and *Gangara thyrsis* (Hesperiidae) were some of the butterflies that had colonized the area following habitat enrichment and host-plant introduction.

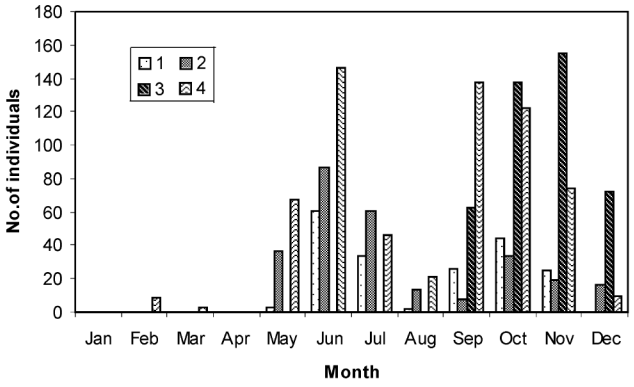

Figure 9. Seasonal trends of selected species of Danaidae (January–December 1999). 1, *Danaus genutia*; 2, *Tirumala limniace*; 3, *Tirumala septentrionis*; 4, *Euploea core*.

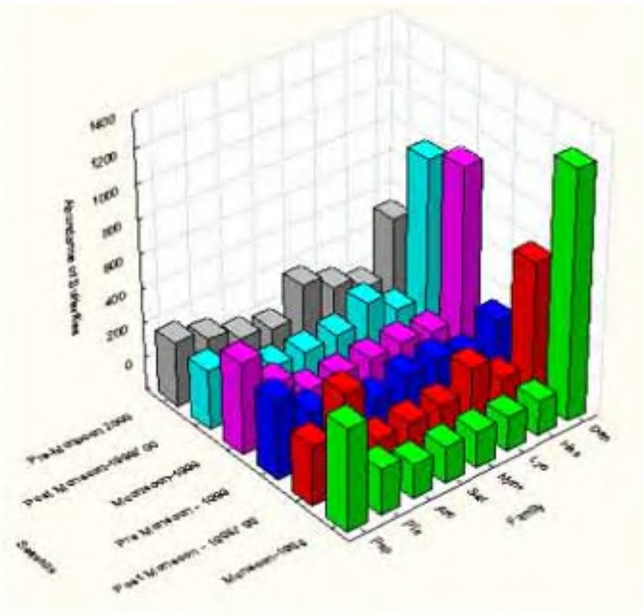

Figure 10. Overall seasonal population trends of various groups of butterflies in the garden from June 1998 to November 2000. Mon, Monsoon; Pre Mon, Pre-monsoon; Post Mon, Post-monsoon; Dan, Danaidae; Hes, Hesperiidae; Lyc, Lycaenidae; Nym, Nymphalidae; Sat, Satyridae; Acr, Acraeidae; Pie, Pieridae; Pap, Papilionidae.

Effect of environmental conditions on butterfly population: The occurrence of different butterflies was correlated with weather conditions like temperature, humidity and rainfall (Table 1). For many butterflies, an average temperature ranging between 25 and 26°C was the most favourable followed by 23 and 25°C as well as 27 and 29°C. Similarly, atmospheric humidity ranging between 80 and 100% was the most preferred range followed by 60 and 80%. With regard to daily rainfall, 50 mm was the most favourable followed by 50–100 mm rainfall. Heavy rainfall was found to be unfavourable since few butterflies were observed above 100 mm of daily rainfall. While butterflies belonging to families Danaidae, Lycaenidae, Papilionidae and Pieridae showed continuous population trends with resident population in the study area, others of families Hesperiidae, Nymphalidae and Satyridae showed erratic population trends. It may be noted here that these groups usually nectar late in the evenings and since the daily counts were completed by 3.30 pm, probably they could have been left out from the countings. Data gathered in this study showed that the families Nymphalidae and Danaidae were significantly correlated with temperature. The occurrence of the former increased with increasing temperature, while in the latter the number of occurrences decreased at higher temperatures. These butterflies are relatively hardy species fond of sunshine. Similarly, significant correlation to humidity was seen in the families Papilionidae and Danaidae (positive), whereby the number of occurrences increased at higher humidity levels. The former generally prefer to fly through shades of lofty trees. In the case of Nymphalidae, a significant (negative) correlation was observed. Papilionidae and Danaidae showed a significant (positive) correlation with rainfall. This information was useful in manipulating butterfly populations within the garden. For instance, certain species like *E. core*, *D. genutia*, *P. aglea* and *T. limniace*, which were usually present during June–October, could be maintained in the study area for longer periods and even during the dry season by maintenance of high humidity with the help of sprinklers and by setting up water sources. Some previous studies are already available on the influence of weather parameters on butterfly populations[14].

Incidence of natural enemies: In this study, insect parasitoids belonging to Braconidae (on larvae of *C. clytia*); Chalcididae (on *E. core*); Scelionidae (on *P. pandiyana* and *T. minos*); Ichneumonidae (on pupae of *T. limniace*) and Diptera (on *Eurema* spp. and *T. sepentrionis*) have been noticed in field populations. Similarly, predatory insects (praying mantis) caused serious problems to the roosting danaid butterflies, *T. limniace*, *T. septentrionis* and *P. aglea*. Besides parasitic and predatory insects, garden lizards and birds were also found in large numbers in the garden, which at times affected the butterfly population. Usually the palatable species (mostly belonging to Papil-

Table 1. Correlation between number of sightings of different families of butterflies and average temperature, average humidity and total rainfall

Family	Correlation		
	Average temperature (°C)	Average humidity (%)	Total rainfall (mm)
Papilionidae	-0.3518^{ns}	0.4072*	0.7530**
Pieridae	-0.0627^{ns}	-0.0091^{ns}	-0.2661^{ns}
Acraeidae	0.2783^{ns}	-0.0099^{ns}	-0.0707^{ns}
Satyridae	-0.2914^{ns}	0.0844^{ns}	0.2708^{ns}
Nymphalidae	0.5723**	−0.5418*	-0.3090^{ns}
Lycaenidae	0.0633^{ns}	-0.1579^{ns}	-0.3598^{ns}
Hesperiidae	-0.3217^{ns}	0.3535^{ns}	0.3024^{ns}
Danaidae	−0.5297**	0.6680**	0.3817*

*Significant at 5% level. **Significant at 1% level. ^{ns}Non-significant.

ionidae) were found to suffer maximum attack, since the unpalatable ones (especially the Danaidae) were avoided by the predators. Adults of *T. minos* were eaten by barbets and spiders and both larvae and adults of *E. core* and *T. limniace* by garden lizards.

Cost for the establishment of a butterfly garden

Investigations on the establishment of the butterfly garden were carried out under a project sanctioned to G.M. by the Ministry of Environment and Forests, Govt of India. The project staff included a Senior Research Fellow and a Technical Assistant. We received Rs 650,000 as assistance, which covered the salary of the project staff and contingencies towards labour charges, stationeries, computer, etc. Now that the methodologies have been standardized, butterfly gardens can be set up at any budget available. A major part of the expenditure is required for infrastructure development, such as landscaping, paths, ponds, fencing and setting up of models depicting the life of a butterfly, information boards, etc. Cost of plants may not be high since host plants can be field-collected and introduced. With regard to staff requirement, one labourer is sufficient to attend the garden work in a moderately sized garden (up to 0.5 ha). A full-fledged garden of this area could be established at about Rs 200,000 to 250,000.

Discussion

Effect of eco-restoration on butterfly population

Because of habitat enrichment and introduction of suitable host plants, there was a marked increase in the number of butterflies visiting the garden, both of individuals and species. Several species of butterflies have also started to colonize the area, setting up local populations. *P. hector*, *P. polymnestor* (Papilionidae); *C. pomona*, *C. pyranthe* (Pieridae); *Moduza procris* (Nymphalidae); *E. caudata* (Satyridae); *T. nyseus*, *R. amor* (Lycaenidae) as well as *D. genutia*, *D. chrysippus*, *T. septentrionis*, *T. limniace*, *P. aglea* and *E. core* (Danaidae) were some of the species that showed population increase in the garden. Even more interesting was the appearance of certain rare species such as *Papilio crino* (Papilionidae); *Appias* sp. (Pieridae); *Junonia orithya* (Nymphalidae); *Spalgis epius*, *Badamia exclamationalis* and *Potanthus* sp. (Hesperiidae), which have been observed visiting the garden.

Important aspects to be considered for butterfly garden programmes

Suitability of site: The location and extent of area available for gardening are other important aspects to be considered. Usually, locations near natural forests are likely to result in the re-colonization of more number of species compared to locations in urban areas. Similarly, the extent of area required for setting up of butterfly gardens varies with species diversity of the area. Although good results were obtained in this study even with the minimum land (0.5 ha) available, a larger area would definitely be a better option considering the diversified habitat requirements of a wide spectrum of butterfly fauna.

Climatic preferences of butterflies: The climatic preferences of various butterflies are important parameters to be considered in butterfly garden programmes. Observations made in this study have shown that the occurrence of various butterflies was in relation to seasons. For many butterflies, May–November was the best season. In extreme climates during monsoon (June and July), dry/windy season (November and December) and the summer months (February and April), the butterfly population tended to be sparse. Among the various weather parameters, temperature, humidity and rainfall appeared to have a strong influence on specific groups of butterflies.

Host preferences: Polyphagy and monophagy are important aspects to be considered while setting up butterfly gardens. Polyphagous species are highly suited for butterfly gardens due to their adaptability to a variety of host

plants. Monophagous species also can be sustained with success as in the case of the Troidine butterflies *T. minos*, *P. aristolochiae* and *P. hector* (all developing on *Aristolochia* spp.) and *T. nyseus* (breeding on *Kalanchoe* spp.). Many of the monophagous species are magnificently coloured and have the potential for prodigious egg production, resulting in a large number of offspring. Many of these species are territorial in habit and maintaining a proper habitat will ensure their presence during the breeding season. The birdwing, *T. minos*, which is a large, colourful

Appendix 1. Data on plants initially present in the study area and those subsequently introduced

Plant species	No. of plants at the beginning of the study	No. of saplings introduced	Plant species	No. of plants at the beginning of the study	No. of saplings introduced
Acestatia sp.*	–	8	*Impatiens* sp.	–	1
Aegle marmelos[+]	–	9	*Ixora chinensis**	2	8
Albizia lebbeck[+]	–	525	*Ixora coccinea**	1	35
Albizia odoratissima[+]*	3	5	*Ixora parviflora**	5	120
Allamanda cathartica	–	5	*Ixora macrothyrsa*[+]*	3	34
Angelonia biflora	–	2	*Jasminum grandiflorum*	–	5
Aristolochia indica[+]	24	75	*Jasminum pubescens**	–	3
Aristolochia grandiflora[+]	–	5	*Jatropha podagirica**	1	2
Bauhinia racemosa	–	1	*Kalanchoe pinnata*[+]*	–	5
Begonia spp.*	–	30	*Kalanchoe suarezensis*[+]*	–	5
Bombax sp.[+]	–	5	*Lantana camara**	25	35
Bryophyllum bipinnata[+]	–	57	*Lantana sellowiana**	–	4
*Caesalpinia pulcherima**	–	20	*Michelia champaka*	–	2
Calliandra inequalifolia	–	1	*Mirabilis jalapa*	–	2
Calotropis gigantea[+]	–	6	*Murraya exotica*[+]	–	18
Cananga odorata	–	3	*Murrya koenigii*[+]	9	15
Carissa carandus[+]*	–	17	*Mussaenda erythrophylla**	–	2
Cassia biflora[+]*	25	7	*Mussaenda incana*	–	2
Cassia fistula[+]*	2	13	*Mussaenda laxa*[+]*	–	14
Cassia occidentalis[+]	–	34	*Mussaenda luteola**	–	2
Cassia tora[+]	–	23	*Nyctanthus arbor-tristis*	–	
Cassia sp.	–	8	*Ocimum gratissimum*	–	2
Catharanthus roseus	–	2	*Ocimum tenuifolium*	–	2
Centranthera sp.	–	2	*Passiflora edulis*[+]	–	8
*Chrysanthemum morifolium**	–	*25*	*Pentas lanceolata**	–	5
Citrus aurantium[+]	–	10	*Plumeria alba*	–	5
Citrus aurantifolia[+]	–	12	*Plumeria rubra**	–	10
Citrus limon[+]	14	37	*Pseudocalyma atata*	–	2
Citrus medica[+]	–	8	*Pyrostegia venusta*	–	2
*Clerodendrum paniculatum**	75	250	*Rosa* sp.	–	2
*Clitoria ternatea**	–	4	*Ruellia affinis*	–	2
Copsia fruiticosa	–	1	*Ruta graveolens*[+]	–	5
Cosmos bipinnatus	–	2	*Salvia splendens**	–	10
Crotalaria pallida	–	5	*Spilanthes* sp.		
Crotalaria retusa	–	25	*Stachytarpheta mutabilis**	–	15
*Cuphea hyssopifolia**	–	25	*Strobilanthes lawsonii*	–	1
*Cuphea miniata**	–	300	*Tabernaemontana coronaria*	–	2
Cycas circinalis[+]	–	2	*Tacca* sp.	–	2
*Doxantha unguis-cati**	–	8	*Tagetes erecta*	–	5
Duranta plumerii	–	1	*Thottea barberi*[+]	–	3
Euphorbia sp.	–	2	*Thottea siliquosa*[+]	–	3
Ficus racemosa[+]	2	3	*Thunbergia erecta**	–	20
Ficus religiosa[+]	–	16	*Thunbergia grandiflora*	–	5
Evolvulus sp.	–	2	*Tithonia diversifolia**	–	3
Gardenia sp.*	–	10	*Turnera ulmifolia**	–	4
Gloriosa superba	–	4	*Tylophora indica*[+]	3	27
*Gomphrena globosa**[+]	–	150	*Vinca rosea**	–	15
Heliotropium keralense	–	5	*Wattakaka* sp.[+]	–	24
Hemidesmus indicus[+]	38	55	*Wattakaka volubilis*[+]	–	28
*Hibiscus rosa-sinensis**	–	12	*Zanthoxylum rhetsa*[+]	20	15
Holostemma ada-kodien[+]	–	15	*Zinnia haageana**	–	20
Hydnocarpus pentandra	–	2			

*Nectar plants; [+]Larval host plants; –, Nil.

butterfly, could be maintained from June to October on its preferred host plant *A. indica*. However, since the larval host plants will be consumed at a high rate, propagation of adequate number of host plants is important in maintaining this species.

Natural mortality factors: Incidence of natural enemies (pathogenic, parasitic and predatory organisms) is also important. The large-scale population build-up in a butterfly garden often leads to similar build-up of natural enemies as well. Laboratory-rearing of field-collected immature stages and release of the reared adults may have to be resorted to ward off parasitism.

Suitability of various butterflies for butterfly garden programmes

The butterflies sighted in this study can be classified into three categories, viz. common – occurring throughout the

Appendix 2. Butterflies sighted from the area during the study period (June 1998–November 2000)

Butterfly family/species	No. of sightings: First half (1–15 months)	Second half (16–30 months)	Total
Papilionidae			
Chilasa clytia[+]	81	15	96
Graphium agamemnon	5	5	10
Graphium sarpedon	7	5	12
Graphium doson[•]			
Pathysa antiphates	19	13	32
Pachliopta aristolochiae	191	175	366
Pachliopta hector[+]*	24	45	69
Pachliopta pandiyana	50	57	107
Papilio buddha[+]*	39	17	56
Papilio crino	0	2	2
Papilio demoleus	2	14	16
Papilio helenus	43	52	95
Papilio liomedon[+]*	1	2	3
Papilio paris	4	1	5
*Papilio polymnestor**	141	69	210
Papilio polytes	217	139	356
*Troides minos**	226	159	385
Pieridae			
Appias spp. (*A. lyncida*[+]; *A. libythea*)[+#]	1	7	8
Catopsilia spp. (*C. pyranthe*; *C. pomona*)[#]	154	93	247
*Delias eucharis**	24	10	34
Eurema spp. (*E. hecabe*; *E. blanda*)[#]	399	288	687
Leptosia nina	1	3	4
Acraeidae			
Acraea violae	0	32	32
Satyridae			
Melanitis leda	17	0	17
Orsotrioena medus	1	0	1
Ypthima huebneri	1	4	5
Mycalesis anaxias[•+]			
Elymnias caudata[•]			
Nymphalidae			
Cupha erymanthis	5	3	8
Vindula erota[•]			
Cirrochroa thais[•]*			
Ariadne merione	0	3	3
Nymphalidae			
Junonia atlites	25	36	61
Junonia hierta	0	3	3
Junonia iphita	36	38	74
Junonia almana[•]			
Junonia lemonias	1	112	113
Junonia orithya	0	1	1
Hypolimnas bolina[+]	0	21	21
Hypolimnas misippus	1	11	12
Moduza procris	0	2	2
Euthalia aconthea[•]			
Neptis hylas	14	6	20
Phalanta phalantha	0	2	2
Lycaenidae			
Arhopala pseudocentaurus	1	0	1
Castalius rosimon[+]	5	0	5
Jamides spp. (*J. celeno*; *J. alecto*)[#]	202	315	517
Rathinda amor	0	6	6
Cheritra freja[•]			
Udara akasa[•]*			
Spalgis epius	0	3	3
Talicada nyseus	0	129	129
Loxura atymnus[•]			
Hesperiidae			
Badamia exclamationis	0	3	3
Celaenorrhinus leucocera	2	0	2
Tagiades litigiosa	1	4	5
Pelopidas mathias	2	1	3
Potanthus sp.	0	3	3
Taractrocera sp.	3	0	3
Telicota ancilla[•]			
Borbo cinnara[•]			
Gangara thyrsis[•]			
Udaspes folus	1	1	2
Danaidae			
Danaus genutia	484	453	937
Danaus chrysippus	13	48	61
Euploea core[+]	789	1186	1975
Parantica aglea	224	424	648
Tirumala limniace	359	382	741
Tirumala septentrionis	693	1590	2283
Grand total	4509	5993	10,502

[#]Species identity limited to generic level due to difficulty in observing species diagnostic characters while conducting visual census.
[•]Species recorded in the study area but not included in the monitoring.
*Species endemic to the Western Ghats.
[+]Species included in the Wildlife (Protection) Act, 1972.

year; seasonal – present only during certain seasons and or rare – sighted only after long intervals. Some Papilionidae (*P. aristolochiae*, *P. polytes* and *P. hector*); Danaidae (*E. core*); Lycaenidae (*T. nyseus*), and Pieridae (*Eurema* spp.) have more or less continuous populations. Such species can be considered as suitable to be maintained in the garden for prolonged periods. Butterflies that are seasonal could be maintained only during specific periods. For instance, during monsoon *T. minos* and *C. clytea* (Papilionidae); *M. leda ismene* (Satyridae); *D. genuita*, *D. chrysippus*, *P. aglea*, *T. septentrionis*, *T. limniace* and *E. core* (Danaidae) and during the summer *P. polytes*, *P. demoleus* and *P. aristolochiae* (Papilionidae); *C. pomona*, *C. pyranthe* and *E. blanda* (Pieridae) and *T. nyseus* (Lycaenidae) could be maintained in the garden. Many Satyridae, Hesperiidae and Nymphalidae, which have erratic populations are present only for a few months and hence may not be dependable as exhibits. However, since many of these are attracted to rotting fruit, toddy or sap, baits using the above materials are likely to attract these butterflies to the gardens. For setting up successful butterfly gardens, a combination of butterflies having continuous and seasonal populations will be useful.

Butterfly gardening is a unique activity that helps in maintaining natural populations of butterflies within narrow strips of land that become available for such activities. By careful selection of host plants and restoration of habitats, a diverse assemblage of butterflies could be sustained in our surroundings.

1. Heal, H. G., An experiment in conservation education: The Drum Manor butterfly garden. *Int. J. Environ. Stud.*, 1973, **4**, 223–229.
2. Mathew, G., Mass rearing of selected butterflies for possible reintroduction in conservation programmes. KFRI research report, 1998, no. 146, p. 44.
3. Newman, L. H., *Create a Butterfly Garden*, John Baker, London, 1967.
4. Pyle, R. M., A history of Lepidopteran conservation, with special reference to its Remingtonian debt. *J. Lepid. Soc.*, 1995, **49**, 397–411.
5. Collins, M. N., *Butterfly Houses in Britain: The Conservation Implications*, IUCN, Cambridge, 1987.
6. Mathew, G., Development of butterfly farming enterprises vis-à-vis conservation and sustainable utilisation of biodiversity. KFRI research report, 2006, no. 286, p. 50.
7. Khoshoo, T. N., Prospects of butterfly farming in India. In *Environmental Concerns and Strategies*, Indian Environmental Society, Natraj Publishers, Dehra Dun, 1984, pp. 236–252.
8. Mathew, G., Conservation of invertebrates through captive breeding: A study with reference to butterflies. KFRI research report, 2001, no. 220, p. 74.
9. Yamamoto, M., Notes on the methods of belt transects of butterflies. *J. Fac. Sci., Hokkaidu Univ., Zool.*, 1975, **20**, 93–116.
10. D'Abrera, B., *Butterflies of the Oriental Region* – Parts I–III, Hill House, Australia, 1982, 1985, 1986, p. 244; 534; 672.
11. Wynter-Blyth, M. A., *Butterflies of the Indian Region*, The Bombay Natural History Society, Mumbai, 1957, p. 523.
12. The Wildlife (Protection) Act, 1972 (Amendment, 1982), Controller of Publications, Govt of India, New Delhi.
13. Ackery, P. R. and Vane-Wright, R. I., *Milkweed Butterflies, their Cladistics and Biology*, British Museum (Natural History), London, 1984, p. 420.
14. Oostermeijer, J. B. G. and Van Swaay, C. A. M., The relationship between butterflies and environmental indicator values: A tool for conservation in a changing landscape. *Biol. Conserv.*, 1998, **86**, 271–280.

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